

RMA

Evan's Data

Theoretical Background

- M. King Hubbert and William W. Rubey
 - Oil company geologists
 - Were aware of several seemingly unrelated pieces of evidence
 - Theoretical work indicated that large overthrust faults were mechanically impossible
 - Geological mapping demonstrated that large overthrust faults existed
 - Oil drillers often had blow-outs because the fluid pressures were much higher than predicted

Theoretical Background

- Hubbert and Rubey reasoned that elevated pore water pressure could carry part of the load, thereby reducing the friction between the two layers
- In other words, elevated pore pressures push rocks apart allowing them to slide with less effort

Theory and Practice

- Evans reasoned that pumping waste water into the well raised the pore pressure
- Elevated pore pressures pushed rocks apart on pre-existing fractures
- Rocks were able to slide at stress levels that existed at the time
- Thus, pumping triggered the earthquakes
- Subsequent work demonstrated the correctness of Evan's analysis

Another Application

- Barry Raleigh and colleagues at USGS
 - Recognized that if earthquakes could be turned on, they could also be turned off
 - They theorized that it might be possible to release stress that was building up before a major earthquake occurred by causing a whole lot of non-destructive, minor earthquakes
 - Needed a place to test this idea

Rangely, Colorado

- Rangely is an active oil field
 - Water was being pumped into the ground
 - 10,000,000 gallons per day
 - Injected into rocks 6,000 feet below the surface
 - Water flushes oil from the pore spaces and opens channels along which the oil can move
 - Oil company geologists had good data on pumping volume and the fluid pressure
 - It would be easy to monitor changes in fluid pressure and earthquake frequency

→ Earthquakes & pore pressure

- The experiment worked
 - Raising pore pressure triggered earthquakes
 - Reducing pore pressure turned them off
 - By monitoring fluid pressure, it was even possible to predict the size of earthquakes that would be produced

A Daring Suggestion

- Control earthquakes on the San Andreas
 - Drill a series of wells
 - Pump water out of A & C to lower fluid pressure and lock the fault
 - Pump water into B to trigger earthquakes
 - Pump water out of B and D to lock the fault
 - Pump water into C to trigger earthquakes
 - Repeat along the fault

Analysis

- Earthquakes should be smaller than $M = 4.5$
 - This requires a depth of 5 km and a slip rate of 2 cm/yr
 - Wells would be drilled 5 km apart and 5 km deep
- Cost
 - Need about 70 wells
 - Each well is 5 km deep
 - Drilling costs $\sim \$100/\text{foot} \times 1700 \text{ ft}$ per well
 - 1.7×10^6 per well $\times 70$ wells = $\$120,000,000$ just to drill

Analysis

- Total cost is high and will be hard to sell
- Pumping needs to be repeated every six months
- It is risky
- It may take a prohibitively large number of small earthquakes to prevent a big one
- This is still in the dreaming stages, but it is an interesting idea
- May be worthwhile at site of large dam or other proposed project